Historical Vadose Zone Contamination from B, BX, and BY Tank Farm Operations

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Abstract: This report compiles information on liquid waste discharged to the soil vadose zone within a 500-meter square area around B, BX, and BY Tank Farms. Planned discharges (i.e., transfers to cribs) and unplanned releases (spills or tank leaks) are considered. Discharges are presented chronologically and placed in the context of tank farm operations.

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ABBRVIATIONS/ACRONYMS

AEC	Atomic Energy Commission
DCRT	Double-contained receiver tank
ITS	In-tank solidification
MW	Metal waste
PUREX	Plutonium and uranium extraction
REDOX	Reduction and oxidation
TBP	Tributyl phosphate
UPR	Unplanned release
UR	Uranium recovery
WIDS	Waste Information Data System

HISTORICAL VADOSE ZONE CONTAMINATION
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1.0 INTRODUCTION

This document is a collection of historical information regarding radioactive contamination of the soil surface and vadose zone in the vicinity of the 241-B, 241-BX, and 241-BY tank farms. Specifically, the historical information is compiled for the tank farms, all known liquid radioactive waste disposal sites (cribs), and all known unplanned releases (UPRs) in an approximately 500 meter square area. The area extends from 12th Street south to the 207-B retention basin and from the 216-BX trenches to the east boundary to B Farm (see Figure 1 in Appendix 7). Releases are included from initial construction in 1944 to the present. A list of disposal sites is contained in Appendix 1. A list of UPRs is included in Appendix 2.

Nonradioactive releases such as fuel spills and septic tanks, and buried radioactive solid waste are excluded from this report. Water discharges to the soil, either from precipitation, water line leaks, or decontamination activities are addressed in Gaddis (1999).

The timeline of events is included in Appendix 3. A glossary is provided in Appendix 4.

The primary focus of this report is on cribs rather than spills. Crib disposal outlets are typically located 3 to 10 meters (9 to 30 ft) below grade, while most spills occur above ground level and contaminate only the surface. Many spill sites were quickly cleaned up and decontaminated. Additionally, the sitewide volume of waste discharged to cribs is more than 100 times the volume of waste leaked from tanks (Consort 1994).

The 216-B-7 cribs, the 216-B-8 crib, and the 216-B-11 reverse wells are located within 241-B tank farm, in Operable Unit 200-BP-7. In addition to the tank farms, this study includes the 216-BY cribs, the 216-B-57 trench and the 216-B-61 crib (never used) in Operable Unit 200-BP-1; the 216-BX trenches in Operable Unit 200-BP-3; and the 216-B-51 French drain in Operable Unit 200-BP-4.

The groundwater beneath the B/BX/BY tank farm complex is 123 m (400 ft) underground and relatively flat. The flatness makes it difficult to ascertain the flow direction. Generally, groundwater in the 200-East Area moves in a northwesterly direction, but there is a southeasterly flow between Gable Mountain and Gable Butte. The location of the division between the flows is not known with certainty, and may be near the B/BX/BY tank farms. The groundwater level beneath 200-East Area has been decreasing gradually since B pond was decommissioned in 1995 (Hartman 1999).

2.0 SUMMARY AND CONCLUSIONS

A number of significant discharges of radioactive contamination to the surface soil and vadose zone occurred throughout the operating history of the Hanford Site. The most significant discharges to the area of interest around the 241-B, -BX, and -BY farm complex are summarized as follows:

- In-tank solidification (ITS) condensate discharged to 216-B-50 and 216-B-57 represents one of the largest volumes of liquid waste, 143 million liters (38 million gal), discharged to the soil at the Hanford Site.
- The B Farm cribs (216-B-7A and B, 216-B-8, and 216-B11A and B) received 100 million liters (26 million gal) of a combination of waste streams 5-6 and 2C, and evaporator condensate.
- With the exception of 216-B-50, the BY cribs received 31.7 million liters (8 million gal) of scavenged tributyl phosphate (TBP) waste (low-level, non-transuranic liquid waste).
- The BX trenches received 14.8 million liters (4 million gal) of waste stream 1C waste.
- The largest spills occurred at 241-BX-102, UPR-200-E-5 (346 700 liters [91,000 gal]) and UPR-200-E-131 (265 000 liters [70,000 gal]).

Other cribs in 200 East Area are outside the scope of this report but are mentioned here for comparison. The 216-B-12 crib received 580 million liters (153 million gal) of TBP plant concentrator condensate. The BC cribs and trenches received 110 million liters (29 million gal) of scavenged TBP waste. The 216-B-9 crib received 36 million liters (10 million gal) of 5-6 waste. The 216-B-5 reverse well received 31 million liters (8 million gal) of 224 waste. The 216-B-10A and 216-B-10B cribs received 10 million liters (3 million gal) of floor drainage from the 292-B Building and some waste from the 222-B decontamination sink and sample slurper.

This report supports previous work on discharges to cribs, ditches, and ponds associated with B Plant (Williams, 1995). Other studies similar to these could be made for the other separation plants and tank farms. Upon completion, these studies can be integrated into a single report. This approach is necessary to account for waste streams that affect more than one plant or tank farm complex. For example, the uranium recovery mission affected U Plant, U farm, B, BX, and BY farms, C farm, and T, TX, and TY farms.

3.0 FACILITIES HISTORICAL BACKGROUND

The 241-B tank farm contains 12 first-generation, reinforced-concrete tanks with mild steel liners covering the sides and bottoms. The tanks are 23 m (75 ft) in diameter and 4.9 m (16 ft) deep, with a capacity of 2 million liters (530,000 gal). The tanks are arranged in four rows of three. The tanks in a row are piped together so that when the first tank fills, it will overflow into the second tank, and the second into the third. Three diversion boxes are provided in B farm.

The farm also contains four smaller tanks that are 6.1 m (20 ft) in diameter and hold 208 000 liters (55,000 gal). These four tanks are piped to diversion box 241-B-252 and to cribs 216-B-7A and 216-B-7B.

The 241-BX tank farm contains 12 tanks of an identical design to 241-B, also arranged in four 3-tank cascades. BX farm has no 208 000-liter tank (55,000 gal) and only one diversion box, 241-BX-153.

The 241-BY tank farm contains 12 second-generation tanks similar to the B and BX farm tanks, but with a 2.9 million liter (758,000 gal) capacity. The BY tanks are arranged in four 3-tank cascades, each of which is piped to the outlet of a BX farm cascade. BY tank farm contains no 208 000 liter (55,000 gal) tanks and no diversion boxes (DiLorenzo 1994).

Other facilities are contained within the B/BX/BY tank farm complex. Liquid waste disposal sites in B farm include the 216-B-8 crib, the BX trenches, and the BY cribs. The 242-B evaporator facility includes the Evaporator Building, the 216-B-11A and 216-B-11B reverse wells in B farm, and the 242-B-151 diversion box. BX farm contains the 244 BXR vault and seven diversion boxes that were used for the uranium recovery mission from 1952 to 1957. The 244-BX double-contained receiver tank (DCRT) is also in the BX farm. Some abandoned ITS equipment is located in the BY tank farm. Piping for saltwell pumping is located throughout the B/BX/BY complex.

The B/BX/BY tank farm complex operations can be separated into five distinct historical eras:

- From 1943 to 1945, B tank farm received liquid waste from the Manhattan Project bismuth phosphate plutonium separation operations.

- From 1946 until B Plant shutdown in 1952, the tank farms were expanded and received liquid waste from the bismuth phosphate operations. Liquid waste disposal to the soil column was initiated.

- From 1952 to 1958, high-level waste was sent to U Plant for uranium recovery and scavenging. Scavenged waste was discharged to cribs. Low-level process condensate was also discharged to cribs.

- ITS operations occurred from 1965 to 1974. Condensate was discharged to cribs.

- Tank farm interim stabilization (saltwell pumping) and isolation began in 1975.

Sanitary water was not supplied to the B/BX/BY tank farms during wartime bismuth phosphate operations, but was supplied to the 241-B evaporator after the war. During uranium recovery operations, sanitary water was supplied to the 271-BXR control house. Later, during ITS operations, sanitary water was supplied to the 2707-BY change house, 241-BY-302 compressor building, and the 241-BY-154 operating building. Currently, all sanitary water piping is capped off and abandoned.

3.1 Wartime Bismuth Phosphate Operations

The 241-B tank farm was constructed in 1943-1944 as part of the Manhattan Project to provide storage for the radioactive liquid waste produced at B Plant. Figure 2 shows the facilities constructed at this time. B Plant used the bismuth phosphate process to separate plutonium from irradiated fuel slugs.

The bismuth phosphate process produced five waste streams:

- MW, also called metal waste, was the byproduct from the plutonium separation phase of the bismuth phosphate process. Metal waste contained unfissioned uranium and approximately 90% of the fission products of the irradiated fuel.

- 1C, also called first-cycle waste, was the byproduct from the first plutonium decontamination cycle of the bismuth phosphate process. This waste contained about 10% of the fission products of the irradiated fuel.

- 2C, also called second-cycle waste, was the byproduct from the second and last plutonium decontamination cycle of the bismuth phosphate process. This waste contained less than 0.1% of the fission products of the irradiated fuel.

- 224 waste was low-level liquid waste from the 224-B plutonium concentrator facility. This waste stream was the primary contributor to plutonium contamination of the soil. This waste was routed to the 216-B-361 settling tank, and then discharged to the 216-B-5 reverse well near B Plant. These two facilities are outside the scope of this study, but are described in Smith (1980).

- 5-6 waste was low-level liquid waste from individual process cells in B Plant. Drainage from the cells was stored in the 5-6 tank before being discharged to the 216-B-361 tank and the 216-B-5 reverse well.

MW, 1C, and 2C were stored in the B farm tanks. These waste streams were also sent to the 241-C tank farm, which is outside the scope of this study (Parker 1944).

Ground disposal of aqueous industrial waste, relying on the ion-exchange properties of the soil to decontaminate the water as it percolates to the aquifer, was a commonly accepted method in the 1940s. The ability of Hanford topsoil and substrate to adsorb radioactive material was tested at the Clinton site in Tennessee (now Oak Ridge National Laboratory) and at the University of California at Berkeley in 1944. Tests determined that ground disposal of 5-6 and 224 was acceptable, but ground disposal of 1C and 2C was not. Methods to treat 1C and 2C to facilitate ground disposal were investigated at the time, but were unsuccessful (Parker 1944; Patterson 1945; Leader 1945).

3.2 Postwar Bismuth Phosphate Operations

In September 1946, the Army Corps of Engineers Manhattan District selected General Electric Company to replace DuPont as site prime contractor. Pursuant to the McMahon Atomic Energy Act of 1946, control of the Hanford Site passed from the Army to the civilian Atomic Energy Commission (AEC) on January 1, 1947. The AEC opted to maintain Hanford as a permanent facility rather than dismantle it, as happened to many other wartime munitions plants. Wartime production had filled all available waste tank space, so plans were made to increase high-level waste storage capacity and to recover some tank space. These plans included disposing of the relatively low-level 2C waste into the ground and concentrating the intermediate-level 1C waste in an evaporator. Plans were also made to recover the unfissioned uranium in the MW (by 1947, most of the world's known supply of uranium was in Hanford waste tanks). From 1947 to 1949, many new facilities were constructed at Hanford. The BX and BY tank farms, facilities for the planned uranium recovery mission (see section 3.3), and other facilities beyond the scope of this report (TX tank farm, Z Plant, H Reactor, DR Reactor, Hot Semi-Works) were all built during this period (Gerber 1991). Figure 3 shows facilities constructed for postwar bismuth phosphate and waste disposal operations.

Disposal of 224 waste in a reverse well was quickly recognized as a "definite mistake" and the waste was rerouted to tank 241-B-201 in 1946. The waste settled in the tank and the supernate overflowed to the 216-B-7A and 216-B-7B cribs. 224 had an average Pu concentration of 99 µg/L and an average β-emitter concentration of 26 µCi/L. Because of the potential for groundwater contamination, the 216-B-5 reverse well was decommissioned in October 1947. The 5-6 waste was temporarily combined with 224 waste and rerouted to the 216-B-7A and 216-B-7B cribs until August 1948, when the 216-B-9 crib near B Plant was built for 5-6 waste disposal. Crib 216-B-9 is outside the scope of this report. Settling tank 241-B-201 was removed from service in October 1948 when it filled with sludge. The influent line was rerouted to 241-B-204, and tanks 241-B-202, -203, and -204 were tied together in a cascade series. The crib line was rerouted to 241-B-202, the last tank in the cascade (Brown 1948; Keene 1951; Williams 1995).

Ground disposal of waste was always regarded as a temporary expedient, and methods of treating 224, 5-6, and other waste types by such means as evaporation, scavenging, or ion exchange were investigated. Experiments with 2C revealed that most activity was concentrated in the sludge settling at the tank bottom, leaving a low-activity supernatant that met existing criteria for ground disposal. The continuing shortage of waste tank space led to the decision to crib 2C after cascading and settling (Piper 1949; Burns 1949; Brown 1950).

The 216-B-8 crib was constructed in 1948 in B farm to dispose of 2C waste. Initially, the crib was piped to a blind riser in B farm, accessible via an overground line, and waste was discharged one month per year. From September 1949 to December 1950, the average activity of 2C discharged to the crib was 1.5 µg/L of Pu and 26 µg/L of beta emitters. In May 1951, the crib line was piped to the 241-B-112 tank, the final tank in the cascade series used for 2C storage, and the cascade continuously overflowed to the crib. In July 1951, when 216-B-9 reached its radionuclide capacity, 5-6 waste was combined with 2C waste and sent to the 241-B-110/111/112 cascade and the B-8 crib. The crib was isolated in December 1951. Between 1948 and 1952, 27.2 million liters (7.2 million gal) of 2C waste was disposed of (H-2-1984; Piper 1949; Brown 1950; Keene 1951; Williams 1995).

The 242-B evaporator was built in 1951 to process 1C waste. Operations began December 14, 1951. The evaporator received 1C waste from feed tank 241-B-106 via the 242-B-151 diversion box. Evaporator condensate was sent to the 216-B-11A and 216-B-11B reverse wells. In the first half of 1952, this condensate had an average plutonium concentration of 0.152 μg/L and an average beta emitter concentration of 0.013 μCi/L. Cooling water was sent to B pond via the 207-B retention basin. Evaporator bottoms were sent to the 241-B-107, -108, and -109 cascade. This waste was then re-evaporated in a second pass. From 1952 to 1954, the 242-B evaporator reclaimed 26.5 million liters (7 million gal) of tank space in B, BX, and BY farms (General Electric 1952; Anderson 1990).

B Plant ceased operations in August 1952 and was shut down in October. When the 242-B evaporator was needed for scavenged TBP waste, ground disposal of 1C was pursued. In May 1953, direct disposal of 1C to specific retention trenches was approved, at a maximum discharge rate of 5280 L/m^2 (150 gal/ft^2) in order to ensure retention of liquid in the soil. Evaporation of 1C was discontinued in August 1953. Approximately 17 million liters (4.5 million gal) of 1C in 200-East and 200-West Areas had not been evaporated at that time. From February to November 1954, 7.5 million liters (2 million gal) of 1C were sent to the BX trenches. Trench disposal of evaporator bottoms was approved in June 1954, and 4.4 million liters (1.2 million gal) were discharged to 216-B-37 in August (Healy 1953; Anderson 1990; Carpenter 1953; Williams 1995). Details of 1C discharges to the BX trenches, including analytical data, are provided in Appendix 5.

Four UPRs are associated with bismuth phosphate operations, three in 1951 and one in 1952. DeFord (1995) describes soil contamination at 241-BX-103 believed to have occurred in 1951, but not assigned a UPR number. The best available information suggests that this contamination is in fact UPR-200-E-5. General Electric (1951) describes a tank leak between 241-BX-102 and 241-BX-103 resulting from a plugged cascade line that released 346 700 liters (91,600 gal) of MW containing 20 500 kg (22.5 tons) of depleted uranium. This is consistent with both DeFord (1995) and the WIDS database printout for UPR-200-E-5. The other 1951 UPRs are UPR-200-E-4 and UPR-200-E-73, both of which leaked an unknown amount of MW from diversion box 241-B-151. In December 1952, 1C leaked from an overground line at 241-BY-107 (UPR-200-E-105) (WIDS).

3.3 Uranium Recovery Operations

U Plant was originally constructed during World War II as a bismuth phosphate plant, but was not needed for that purpose so the facility was used as a simulator. It was modified in 1951 for uranium recovery operations using the TBP process. For this reason, U Plant was frequently referred to as the "TBP Plant." Beginning in 1952, MW was sluiced from B, BX, and BY farms, treated in the 244-BXR vault, and transferred via the 241-BXR-151 diversion box to U Plant. MW from C, T, and U farms was also sent to U Plant for uranium recovery. Until T Plant was shut down in 1956, newly generated MW was also sent to U Plant for uranium recovery (Rodenhizer 1987; Anderson 1990).

The uranium recovery facilities in the B/BX/BY tank farm complex include the 244-BXR vault, seven diversion boxes (one for B farm and three each for BX and BY farms) and associated transfer lines, modifications to the B farm underground piping system, and the BY cribs. Figure 4 shows facilities constructed for the uranium recovery mission.

Uranium recovery operations produced two waste streams. TBP waste, concentrate from the waste concentrator, was returned to the tank farms, including the B/BX/BY complex. The design called for the same volume of TBP waste to be produced as the volume of MW processed, but inefficiencies in the process resulted in approximately two liters of TBP waste produced for every liter of MW processed. A total of 215 million liters (56.7 million gal) of TBP waste was produced. Low-level waste included condensate from the feed concentrator, waste concentrator, and HNO_3 fractionator. This waste was discharged to various cribs that are outside the scope of this report. Cooling water and cell drainage were discharged to U pond, also outside the scope of this report (Waite 1991; DiLorenzo 1994; General Electric 1951b).

Despite additional tank farm construction and ongoing volume reduction efforts, waste tank space was not sufficient to support both the uranium recovery mission and plutonium production. To reduce the volume of stored waste, TBP waste was concentrated in the 242-T and 242-B evaporators beginning in September 1953. Additionally, a ferrocyanide scavenging process was developed to remove the principal long-lived fission products, ^{137}Cs and ^{90}Sr, from the TBP waste to enable disposal of the waste supernate to cribs. Beginning in September 1954, TBP waste was scavenged in U Plant to remove Sr and Cs. Beginning in November 1955, TBP waste that had been returned to the B/BX/BY farms and to C farm was retrieved and scavenged in the 244-CR vault. From scavenging (in U Plant or 244-CR), waste was sent to the BY tank farm for settling, then to the BY cribs from 1954 to 1957 (Waite 1991).

Average settling time was approximately a month. After settling, the supernate was sampled and, if within limits, discharged to the cribs. Crib size and spacing were based on anticipated discharge rates. Criteria for cribbing were a maximum of 3.17E07 L/m^2 (6,000 gal/ft^2), and a maximum concentration of ^{137}Cs and ^{90}Sr of 0.08 to 0.10 µCi/mL. This would result in a maximum of 2 000 curies of each isotope per 3.2-m^2 (30 ft^2) crib. Concentrations of 0.2 µCi/mL could be discharged if the volume were reduced proportionally, but could never be outside the range of 1.59E07-3.1E07 L/m^2 (3,000-6,000 gal/ft^2) because of scattering and percolation limitations. Discharge of concentrations greater than 0.2 µCi/mL required prior approval of the Radiological Sciences Department. Samples were taken from the discharge line for every 189 000 L (50,000 gal) discharged. (Clukey 1951)

Cribbing of scavenged TBP waste began in November 1954, the week after 1C cribbing was finished. Approximately 155 million liters (41 million gal) of scavenged TBP waste was discharged to the ground. Of this, approximately 44 million liters (12 million gal) resulted from in-farm scavenging in the 244-CR vault. A total of 34 million liters (9 million gal) was discharged to the BY cribs, with an additional 1.5 million liters (400,000 gal) discharged to 216-B-42, one of the BX trenches, in 1955 (Waite 1991; Williams 1995). Details of scavenged TBP waste discharges to the BY cribs, including analytical data, are provided in Appendix 6.

In May 1955, groundwater contamination was noted at the 216-B-8 crib, where the 2C waste had been discharged. In October 1955, groundwater contamination was noted at the 216-B-42 trench. Discharge of scavenged TBP waste to the BY cribs was discontinued in December 1955 when ^{137}Cs was detected in the groundwater (seven of the eight cribs were in use at that time). Waste was diverted to the BC cribs (outside the scope of this report). In February 1956, ^{60}Co was detected under the BY cribs at well E33-4 at 100 times the allowable limit (Kasza 1993; DeFord 1995).

Eight UPRs are associated with uranium recovery operations. In April 1953, MW leaked from an overground line at 241-B-102 (UPR-200-E-108). In June 1953, the underground cooling water drain line from 242-B to the 207-B retention basin leaked (UPR-200-E-79). In November1953, TBP leaked from a tank riser at 241-B-104 (UPR-200-E-109). Three diversion box leaks occurred in 1954 (UPR-200-E-6 and UPR-200-E-75 at 241-B-153, and UPR-200-E-74 at 241-B-152). In September 1955, scavenged TBP overflowed from flush tank 216-BY-201 (UPR-200-E-9).

There is a discrepancy regarding the type of waste involved in UPR-200-E-110. WIDS states that UPR-200-E-110 leaked 1C waste from a valve pit at 241-BY-112 in August 1955. However, Anderson (1990) states that 241-BY-112 never held 1C. MW was being sluiced from 241-BY-112 in August 1955, and this is most likely the correct waste type.

3.4 In-Tank Solidification Operations

Following the end of uranium recovery operations, many tanks in the B/BX/BY farms received PUREX coating waste from C farm. Concern over the integrity of single-shell tanks in the early 1960s (the first confirmed tank leak was in 1959) resulted in the decision to remove all liquid waste supernate from single-shell tanks. The ITS system was used to concentrate nonboiling waste to produce a partially mobile salt cake (Liverman 1975; Rodenhizer 1987; Anderson 1990).

Two ITS systems were installed in the BY tank farm. ITS#1 (heated air circulated through tank waste) was installed for tanks 241-BY-101 and 241-BY-102 and began operation in 1965. ITS#2 (in-tank heater) was installed for 241-BY-111 and 241-BY-112 and began operation in 1968. By 1971, ITS#2 extended to all remaining BY tanks, and ITS#1 was converted into a cooler for ITS#2. The ITS system was tied into BX farm in 1971 and B farm in 1973. Disappointing performance resulted in ITS being superseded by saltwell pumping and the system was shut down in 1974 (Anderson 1990). The ITS facilities are shown in Figure 5.

Beginning in 1968, all tanks constructed or planned have been a double-shell design. The AEC decided in 1968 to remove all liquid waste from single-shell tanks by 1975, using ITS. When this proved unfeasible, saltwell pumping replaced ITS as a method of liquid waste removal (Williams 1968; Liverman 1975).

The ITS system produced two waste streams. Concentrate from the ITS units was discharged to the B/BX/BY tank farms. The concentrate contained an average of 50% interstitial liquid, which was later reclaimed by saltwell pumping. The 242-T and 242-S evaporators performed a similar ITS function in 200-West Area (Liverman 1975; Anderson 1990).

Condensate from ITS#1 was sent to the 216-B-50 crib from ITS#1 startup in 1965 to ITS #2 shutdown in 1974. The 216-B-60 trench was constructed in 1969 to replace this crib but was never used. Condensate from ITS#2 was sent to the 216-B-57 trench from ITS#2 startup in 1968 to shutdown in 1974 (Liverman 1975; Williams 1995).

ITS received some waste from waste fractionization operations that were conducted from 1968 to 1978 in B Plant. Waste fractionization removed heat-producing isotopes, principally ^{90}Sr and ^{137}Cs, from PUREX waste to allow safe evaporation of this waste to salt cake. B Plant was reconfigured to remove Cs and Sr from the waste, and the 244-AR vault was constructed to serve as a processing and transfer facility. Boiling waste from the PUREX plant, or PUREX waste stored in A and AX tank farms, was sent to B Plant via the 244-AR vault. REDOX waste supernate from SX farm was also sent to B Plant for waste fractionization. High-level waste from waste fractionization was sent to single-shell tanks in A and AX farms in the 1960s and early 1970s, and to double-shell tanks in AY farm in the late 1970s. Low-level liquid waste was concentrated in an evaporator in cell 23 of B Plant, with the bottoms routed to ITS and the condensate discharged to various cribs that are outside the scope of this study (Caudill 1964; Liverman 1975; Williams 1995).

Four UPRs are associated with ITS operations. Two diversion box leaks occurred in January 1968: UPR-200-E-38 at 241-B-152 and UPR-200-E-76 at 241-B-153. In January 1972, a pump being transported to the burial ground for disposal dripped contamination from the truck to the roadway (UPR-200-E-43). In November 1972, an unknown amount of contaminated flush water sprayed from a pump in 241-BY-112 (UPR-200-E-116) (WIDS).

3.5 Stabilization and Isolation

Eight leaking single-shell tanks were identified in B/BX/BY between 1968 and 1974. In 1971, a leak from 241-BX-102 (UPR-200-E-131) resulted in an underground plume that required relocation of nearby water lines. In accordance with Hanford operating policy at the time, liquid waste removal from tanks of questionable integrity was expedited and the tank was removed from service. Interstitial liquid was removed by saltwell jet pumping. The process of removing all supernatant and as much drainable liquid as possible is known as interim stabilization and was started in 1972 (Liverman 1975; Anderson 1990; WIDS).

The B/BX/BY complex tanks were interim stabilized beginning in 1975, with the interstitial liquid pumped to receiver tank 241-BX-104, and from there to the 242-S evaporator via the 241-ER-151 diversion box (later sent to the 242-A evaporator). The saltwell system for B/BX/BY farm included a pump pit for each tank, the saltwell and jet pump, underground piping from the pump pits to the receiver tank, and associated instrumentation and controls (Smith 1975; Grimes 1977).

AEC policy was to direct all liquid waste to double-shell tanks. To discontinue the use of a single-shell tank as the saltwell waste receiver, the 244-BX DCRT was constructed in 1983, tying into the existing saltwell piping. See Figure 6 for an illustration of the saltwell system piping arrangement. The 244-BX is the only facility available to transfer waste to and from the B/BX/BY tank farms (Mirabella 1977; Hanson 1980; Hanlon 1999; WIDS).

Six tanks in the B/BX/BY complex were interim stabilized prior to construction of 244-BX. All tanks in the B/BX/BY complex are now interim stabilized, except 241-BY-105 and 241-BY-106 (Hanlon 1999).

Following interim stabilization, single-shell tanks were interim isolated by establishing at least one physical barrier between the tank contents and the environment, to preclude inadvertent addition of liquid. This was done by cutting and blanking all process piping to and from the tank, blanking all risers, and equipping the tank with a filtered ventilation system. The first tank to be isolated was 241-BX-102, in October 1980. Tanks B-101, BX-101, and BX-108 were isolated in 1982. The remaining tanks in B farm, and 241-BX-103, were isolated in 1985. All B and BX farm tanks are interim isolated. Seven BY farm tanks are interim isolated, and five tanks are partially interim isolated. The 244-BXR vault, the 241-B-301 catch tank, the 241-BX-302A catch tank, and all diversion boxes and transfer lines were isolated by project B-231 in 1984-1985 (Liverman 1975; Hanlon 1999; WIDS).

Three UPRs are associated with stabilization and isolation: one tank leak in 1976 (UPR-200-E-130), and two surface contamination incidents in 1978 (UPR-200-E-89) and 1985 (UPR-200-E-101). No UPRs have been recorded since 1985 (WIDS).

4.0 MONITORING TEST WELLS

Seven monitoring wells were originally drilled in each tank farm as part of original construction to check for tank leakage. To avoid groundwater contamination, these wells were drilled only to 49 m (150 ft) and did not extend to the upper aquifer (groundwater depth was 82 m [250 ft]). One well in 241-BY farm was drilled to 90 m (275 ft) as a groundwater monitoring well. Wells were checked weekly (Parker, 1944; Brown 1950). An extensive discussion of monitoring wells inside the tank farms is included in Gaddis (1999).

Knowledge of the groundwater hydrology of the Hanford area at time of initial construction was limited to a few reports from the 1910s and 1920s, all of which were general in scope and limited in content. The continuing need to dispose of 1C and 2C waste to the ground led the AEC to contract with the U.S. Geological Survey to drill a series of test wells in late 1946 to evaluate the 200 plateau soil for waste disposal suitability, and for general groundwater research. Three wells were drilled near the 216-B-7 cribs in May 1947. (Brown 1950).

An unusual structure is the Health Instruments shaft by the 216-B-8 crib. This shaft was constructed as part of the 1947-1949 expansion for collecting liquid and sediment samples. It is 18 m (55 ft) deep and consists of prefabricated concrete sections, 2.6 m (8 ft) in diameter, 2 m (6 ft) high, and 246 cm (9 in) thick. Steel laterals 164 cm (6 in) in diameter and 7.2 m (22 ft) long are installed in holes in the walls of the concrete sections 3.3 m (10 ft) and 6.6 m (20 ft) below the crib and carefully emplaced to minimize disturbing the sediments. Openings in the tops of the laterals permit liquid to enter and collect in sample cups. Other holes were made in the shaft wall facing the crib and covered with removable cups to enable collection of sediment samples. Liquid seepage into the shaft made it necessary to reduce the rate of discharge to the 216-B-8 crib. The shaft was later used as a run-in pit for contaminated pumps (H-2-738; Brown 1950).

Other monitoring wells were drilled near cribs to monitor vadose zone contamination. Wells were built for the BY cribs (1 per crib) as part of original construction. Additional test wells were drilled in 1966 at the BY cribs. In the early 1970s, additional wells were drilled around individual tanks to more closely monitor tank leakage. Other test wells were drilled to monitor groundwater contamination (Liverman 1975). An extensive discussion of monitoring wells is included in Gaddis (1999).

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APPENDIX 1: INTENTIONAL RELEASE QUANTITIES

Site Number	Location	Operation Dates	Source	Waste Type	Waste Volume (liters)	Comments
216-B-7A	241-B farm	9/46-12/54	224-B	224	$4.3x10^7$ (7A and 7B combined)	Radionuclide capacity reached
		10/47-8/48	221-B	5-6		
		12/54-9/58	224-B	Cleanout		
		12/54-10/61	221-B	5-6		
		10/61-5/67	221-B	Decon Waste		
216-B-7B		9/46-5/67	216-B-7A	Overflow		
216-B-8	241-B farm	4/48-12/51	221-B	2C	$2.72x10^7$	
		7/51-12/51	221-B	5-6		
		12/51-12/52	224-B	Decon waste		
216-B-11A	241-B farm	12/51-12/54	242-B	1C condensate	$2.96x10^7$ (11A and 11B combined)	
216-B-11B			216-B-11A	Overflow		
216-B-35	BX trenches	2/54-3/54	221-B	1C	$1.06x10^6$	
216-B-36	BX trenches	3/54-4/54	221-B	1C	$1.94x10^6$	
216-B-37	BX trenches	8/54	242-B	1C Bottoms	$4.32x10^6$	
216-B-38	BX trenches	7/54-8/54	221-B	1C	$1.43x10^6$	
216-B-39	BX trenches	12/53-11/54	221-B	1C	$1.47x10^6$	
216-B-40	BX trenches	4/54-7/54	221-B	1C	$1.64x10^6$	
216-B-41	BX trenches	11/54	221-B	1C	$1.44x10^6$	
216-B-42	BX trenches	1/55-2/55	221-U	TBP (PFeCN)	$1.5x10^6$	
216-B-43	BY cribs	11/54	221-U	TBP	$2.1x10^6$	Contaminated by UPR-200-E-9 in 1955
216-B-44	BY cribs	11/54-3/55	221-U	TBP	$5.6x10^6$	
216-B-45	BY cribs	4/55-6/55	221-U	TBP	$4.9x10^6$	
216-B-46	BY cribs	9/55-12/55	221-U	TBP	$6.7x10^6$	
216-B-47	BY cribs	9/55	221-U	TBP	$3.7x10^6$	
216-B-48	BY cribs	11/55	221-U	TBP	$4.1x10^6$	
216-B-49	BY cribs	11/55-12/55	221-U	TBP	$6.7x10^6$	
216-B-50	BY cribs	1/65-1/74	ITS#1	Condensate	$5.9x10^7$	
216-B-51	NE of 241-B	1/56-1/58	BC crib line	Flush drainage		
216-B-57	W of 241-BY	2/68-6/73	ITS#2	Condensate	$8.4x10^7$	
216-B-61	NW of 241-BY	Built 1969	ITS#2	None	None	Never used

APPENDIX 2: UNPLANNED RELEASE QUANTITIES

Site Number	Location	Date	Leak Type	Waste Type	Waste Volume (liters)	Comments
UPR-200-E-4	241-B-151	Fall 1951	Diversion Box Leak	MW		
UPR-200-E-5	241-BX-102	3/20/1951	Plugged Cascade Outlet	MW	346,700	
UPR-200-E-6	241-B-153	1954	Diversion Box Leak			
UPR-200-E-9	216-BY-201	9/15/1955	Tank Overflow	TBP	41,600	
UPR-200-E-38	241-B-152	1/4/1968	Diversion Box Leak			
UPR-200-E-43	Road near BY farm	1/10/1972	Spill From Truck			
UPR-200-E-73 (UN-216-E-1)	241-B-151	1951	Diversion Box Leak	MW		
UPR-200-E-74 (UN-216-E-2)	241-B-152	Spring 1954	Diversion Box Leak			
UPR-200-E-75 (UN-216-E-3)	241-B-153	1954	Diversion Box Leak			
UPR-200-E-76 (UN-216-E-4)	241-B-153	1/4/1968	Piping Leak	B Plant 9-2 Tank	20,441	
UPR-200-E-79 (UN-216-E-7)	Between 242-B and 207-B	June 1953	Underground Piping Leak	Cooling Water		
UPR-200-E-89 (UN-216-E-17)	BY cribs	1978	Surface Contamination			
UPR-200-E-101 (UN-216-E-30)	242-B	1985	Surface Contamination			
UPR-200-E-105	241-BY-107	12/16/1952	Overground Piping Leak	1C	87,000	
UPR-200-E-108	241-B-102	4/14/1953	Overground Piping Leak	MW		
UPR-200-E-109	241-B-104	11/11/1953	Riser Leak	TBP	568	
UPR-200-E-110	241-BY-112	8/7/1955	Valve Pit Leak	MW		
UPR-200-E-116	241-BY-112	11/20/1972	Piping Leak	Flush Water		
UPR-200-E-127	241-B-107	1968	Tank Leak		30,300	
UPR-200-E-128	241-B-110	1969	Tank Leak		31,500	
UPR-200-E-129	241-B-201	1968	Tank Leak		4,500	
UPR-200-E-130	241-B-203	1977	Tank Leak		1,135	
UPR-200-E-131	241-BX-102	1971	Tank Leak		265,000	
UPR-200-E-132	241-BX-102	1974	Tank Leak		9,500	
UPR-200-E-133	241-BX-108	1974	Tank Leak		9,500	
UPR-200-E-134	241-BY-103	1973	Tank Leak		19,000	
UPR-200-E-135	241-BY-108	1972	Tank Leak		19,000	

APPENDIX 3: HISTORICAL TIME LINE OF EVENTS

1943-1944:	Construction of B Plant and B Farm
Apr 13 1945:	B Plant begins operations. MW, 1C, 2C from B Plant discharged to B Farm.
Aug 11 1945:	WWII ends
Sep 1946:	216-B-7A&B cribs begin operation (B Plant 224 waste, via 241-B-201)
Jan 1 1947:	Control of Hanford Site shifts from U.S. Army Corps of Engineers to Atomic Energy Commission
Jan 1 1947:	General Electric replaces DuPont as Hanford prime contractor.
Aug 1947:	Large construction effort. B-8 crib, BX & BY farms, UR facilities, other
Jan 1948:	MW and 1C from B-Plant operations discharged to BX farm
Feb 1948:	2C from B Farm to 216-B-8 crib
Mar 1950:	MW and 1C discharged to BY farm
Mar 20 1951:	UPR-200-E-5, underground cascade piping MW leak at 241-BX-102
Jul 1951:	B Plant 5-6 waste sent to 216-B-8 crib
Mid-1951:	Continuous overflow from 241-B-112 to 216-B-8
Fall 1951:	UPR-200-E-4, diversion box MW leak at 241-B-151
Dec 1951:	Finish 2C discharge to 216-B-8; isolate crib
Dec 14 1951:	1C to 242-B: condensate to 216-B-11 reverse wells, cooling water to 207-B, bottoms to tank farms
1951-1952:	UPR-200-E-73 (UN-216-E-1), diversion box MW leak at 241-B-151
Oct 1952:	B Plant shut down
Nov 1952:	MW from B, BX, BY Farms pumped to U plant for uranium recovery (via BXR vault)
Dec 1952:	UPR-200E-105, overground piping 1C leak at 241-BY-107
Apr 14 1953:	UPR-200-E-108, overground MW leak at 241-B-102
Jun 1953:	UPR-200-E-79 (UN-216-E-7), underground pipeline cooling water leak between 242-B and 207-B
Sep 20 1953	TBP waste sent to 242-B for evaporation
Nov 11 1953:	UPR-200-E-109, riser TBP leak at 241-B-104
Dec 1953:	1C first discharged to BX trenches
1954:	UPR-200-E-6, diversion box leak at 241-B-153
Spring 1954:	UPR-200-E-74 (UN-216-E-2), diversion box leak at 241-B-152
Aug 1954:	Evaporator bottoms from 242-B to 216-B-37
Sep 1954:	Begin TBP scavenging in U Plant
Nov 1954	Finish 1C discharge to BX trenches
Nov 1954:	Scavenged TBP from U Plant to BY cribs
Nov 1954:	242-B shutdown; isolate 216-B-11A&B wells
1954-1955:	UPR-200-E-75 (UN-216-E-3), diversion box leak at 241-B-153
Jan 1955:	Scavenged TBP from U Plant to 216-B-42 trench
May 1955:	Groundwater contamination noted at 216-B-8 crib
Aug 1955:	Groundwater contamination noted beneath BY cribs
Aug 7 1955:	UPR-200-E-110, valve pit MW leak at 241-BY-112
Sep 15 1955:	UPR-200-E-9, flush tank TBP overflow at 216-BY-201 (within UPR-200-E-89)
Oct 1955:	Groundwater contamination noted at 216-B-42 trench
Nov 1955:	Begin TBP scavenging in 244-CR vault

Dec 1955:	Cs-137 detected in groundwater under BY cribs; TBP discharge rerouted to BC cribs instead
Jan 1956:	Scavenged TBP from line flush to 216-B-51 French drain
Feb 28 1956:	Co-60 detected under BY cribs at well E33-4, 100 times over limit
Jan 1 1958:	UR project completed
Mar 1965:	ITS#1 begins in BY farm; condensate to 216-B-50, cooling water to 207-B
May 1967:	Isolate 216-B-7A&B cribs
1968:	B Plant restarted for waste fractionization.
Jan 4 1968:	UPR-200-E-38, diversion box leak at 241-B-152
Jan 4 1968:	UPR-200-E-76 (UN-216-E-4), underground line leak at 241-B-153
Feb 1968:	ITS#2 begins in BY farm; condensate to 216-B-57, cooling water to 207-B
1968:	UPR-200-E-127, tank leak at 241-B-107
1968:	UPR-200-E-129, tank leak at 241-B-201
1969:	UPR-200-E-128, tank leak at 241-B-110
1971:	UPR-200-E-131tank leak at 241-BX-102
Aug 24 1971:	ITS#1 converted to cooler for ITS#2
Jan 10 1972:	UPR-200-E-43, truck spill on road near BY farm
1972:	UPR-200-E-135, tank leak at 241-BY-108
Nov 20 1972:	UPR-200-E-116, flush water spill at 241-BY-112
May 1973:	UPR-200-E-134, tank leak at 241-BY-103
1974:	UPR-200-E-132, tank leak at 241-BX-102
1974:	UPR-200-E-133, tank leak at 241-BX-108
Jun 30 1974:	ITS units shut down
1975:	Begin interim stabilization of B/BX/BY complex
Apr 1976:	UPR-200-E-130, tank leak at 241-B-203
1978:	UPR-200-E-89 (UN-216-E-17), surface contamination at BY cribs, spread by wind
1978:	Waste fractionization in B Plant discontinued.
Oct 1980:	Begin interim isolation of B/BX/BY complex
1983:	Construct 244-BX DCRT
1984:	Isolation of most diversion boxes
1985:	Isolation of catch tanks, BXR vault, B farm SSTs
Feb 1985:	B Plant permanently shut down
Aug 1985:	UPR-200-E-101 (UN-216-E-30), surface contamination at 242-B

APPENDIX 4: GLOSSARY

Crib: An underground liquid waste disposal facility filled with soil and/or crushed gravel utilizing the ion exchange properties to remove radioactive contamination. Cribs were typically operated until contamination was observed in the groundwater beneath the crib.

Specific Retention Trench: An unlined excavation used for the disposal of a designated volume of low-level or intermediate-level radioactive waste. Liquid is retained in the trench soil and does not migrate to the groundwater.

Reverse Well: A buried vertical pipe with the lower end open or perforated to allow seepage of liquid waste into the ground.

French Drain: A buried horizontal pipe filled with rock, open-ended or perforated, for disposal of liquid waste by seepage into the ground.

Double-Contained Receiver Tank (DCRT): Facility consisting of a reinforced concrete structure containing a receiver tank for radioactive liquid waste, a pump pit, and a filter pit.

Interim Stabilization: The process of pumping all supernatant and as much drainable interstitial liquid as possible from a single-shell tank to minimize the volume of liquid available to leak into the ground.

Interim Isolation: The process of establishing at least one physical barrier to any credible source of liquid addition to a single-shell tank, or other facility such as a diversion box, and separating the tank atmosphere from the outside air by a filtered ventilation system.

APPENDIX 5: FIRST CYCLE WASTE DISPOSAL TO BX TRENCHES

FIRST CYCLE WASTE DISPOSAL TO BX TRENCHES										
Date	Trench	Tank	Gallons	Liters	Pu (g)	U (g)	β (Ci)	Cs (Ci)	Sr (Ci)	Sb (Ci)
12/1/53	B-39	BX-112	206250	7.81E05	1.38	2200	905	430	11.7	N/A
2/18/54	B-35	BX-110	254380	9.63E05	0.48	1330	500	558	1.8	26
4/27/54	B-36	BX-111	467500	1.77E06	0.32	1270	1030	1010	6.2	N/A
7/17/54	B-38	BY-110	397375	1.50E06	1.20	45000	3000	6.3	1850	N/A
8/54	B-40	BY-110	298375	1.13E06	0.90	34000	1040	2.4	280	N/A
10/54	B-39	BY-106	200793	7.60E05	0.13	3990	350	450	0.38	44
10/54	B-41	BY-106	398943	1.51E06	0.24	7940	700	890	0.76	88
11/1/54	B-40	BY-106	154822	5.86E05	0.10	3080	270	350	0.29	34

Curies are 1955 values; uncorrected for decay.

There is a discrepancy regarding the dates of the 241-BY-106 discharges. Paas and Heid (1955) give dates of 11/1/54 for the discharges to 216-B-39 and 216-B-41 and 4/1/54 for the discharge to 216-B-40. The tank farm weekly summary (Bradley 1954) for the week of 10/22/54 to 10/29/54 describes a discharge of 500,000 gal from BY-106 to the trench; and for the week of 10/29/54 to 11/5/54 describes a discharge of 250,000 gal, which is also described as the final first-cycle waste transfer. The above dates are based on Bradley (1954) and are believed to be correct.

There is also a discrepancy regarding the volumes of the BY-106 discharges, although the total amount is not in dispute. Bradley describes the discharges as 500,000 gallons the first week and 250,000 the second. Paas and Heid describe the discharges as 600,000 gallons the first week and 150,000 the second. The above volumes are taken from Paas and Heid in order to retain the analytical data. The individual trench volumes differ slightly from Maxfield (1979) but agree within 10%.

FIRST CYCLE EVAPORATOR BOTTOMS DISPOSAL TO 216-B-37								
Date	Tank	Gallons	Liters	Pu (μCi/cc)	U (μCi/cc)	Cs (μCi/cc)	Sr (μCi/cc)	pH
8/1/54	B-109	1.30E05	4.92E05	2.38E-05	6.2E-07	0.82	3.7E-03	7.9
8/8/54	B-109	2.70E05	1.02E06	2.38E-05	6.2E-07	0.82	3.7E-03	7.9
8/31/54	B-107	3.20E05	1.21E06	2.38E-06	9.8E-07	0.82	7.4E-03	8.0
8/27-9/3	B-108	2.80E05	1.06E06	1.19E-05	2.7E-07	0.56	1.0E-03	8.1
9/3-9/10	B-108	2.50E05	9.46E05	1.19E-05	2.7E-07	0.56	1.0E-03	8.1
Totals		1.25E06	4.43E06	0.91 g	3750 g	3070 Ci	15.8 Ci	N/A

Curies are 1955 values; uncorrected for decay.

There is a discrepancy in the waste volumes for the 241-B-108 and 241-B-109 discharges. Bradley describes two discharges from B-109 totaling 400,000 gallons. Paas and Heid describe the total volume as 364,375 gallons. Bradley describes a discharge from B-107 and B-108 of 600,000 gallons and a second discharge from B-108 of 250,000 gallons. Paas and Heid describe the B-107 discharge as 320,375 gallons. If this is correct (and it agrees with the waste status summaries), the first B-108 discharge would be 280,000 gallons. The total for B-108 would then be 530,000 gallons. However, Paas and Heid describe the B-108 total as 449,625 gallons. Maxfield (1979) describes the total discharge to the trench as 4.32E06 L, which agrees within 10%.

APPENDIX 6: SCAVENGED TBP WASTE DISPOSAL TO BY CRIBS

Discharges of hundreds of thousands of gallons took several days to accomplish. Scavenging batch no. 4 was sent to specific retention trench 216-B-42 and not sampled. Batches 6, 8, and 9 were retained in the tanks and not cribbed. Batch 10 was cribbed but not sampled. Cs-137 contamination was found in the groundwater, and batches 21 through 30 were sent to the BC cribs. Disposal was halted after batch 30 when Co-60 contamination was discovered in the groundwater under the BY cribs. Subsequent batches were discharged to the BC specific retention trenches (Abrams, 1956).

SCAVENGED TBP WASTE DISPOSAL TO BY CRIBS										
Scavenging batch	1	2	3	4	5	7	10	11	12	13
To Crib	216-B-43	216-B-44	216-B-44	216-B-42	216-B-44	216-B-45	216-B-45	216-B-48	216-B-49	216-B-46
Date	11/6/54	12/10/54	12/22/54	2/13/55	3/8/55	4/5/55	6/17/55	11/2/55	12/7/55	8/29/55
Gallons	563,750	398,750	402,187	402,875	671,000	712,250	591,937	525,250	603,650	617,375
SAMPLE DATA				Not sampled			Not sampled			
Ph	N/A	8.9	9.0		10.0	9.4		9.3	8.9	9.9
Cs, μCi/mL	0.022	0.009	0.13		0.18	0.15		0.020	0.018	0.005
Sr, μCi/mL	0.63	1.13	0.22		0.27	0.83		0.39	0.73	0.54
Total β, μCi/mL	1.47	3.65	2.34		4.70	8.24		11.07	9.51	19.66
Total α, cpm/gal	50,000	80,000	20,000		1,100,000	900,000		300,000	500,000	1,200,000
PO_4, M	N/A	N/A	N/A		N/A	N/A		0.123	0.052	0.093
U, lb/gal	4.90	0.85	0.22		0.10	0.20		0.70	26.0	0.32
NO_3, lb/gal	N/A	N/A	N/A		N/A	N/A		1.76	1.82	0.96
Solids, wt. %	N/A	N/A	N/A		N/A	N/A		33.6	35.0	26.0
R.E., μCi/mL	0.75	1.49	0.22		0.25	1.57		0.25	1.72	0.93
Ce, μCi/mL	0.15	0.051	0.91		0.40	1.66		0.47	0.67	2.33
Zr-Nb, μCi/mL	N/A	0.31	0.24		0.46	1.33		1.05	0.59	0.05
Ru, μCi/mL	0.023	0.26	0.29		1.80	2.06		0.83	3.14	5.44
Sb, μCi/mL	0.009	0.23	0.33		0.07	0.31		0.38	0.39	0.69

Curies are 1955 values; uncorrected for decay.

N/A: not analyzed
R.E.: rare earth elements

SCAVENGED TBP WASTE DISPOSAL TO BY CRIBS										
Scavenging batch	14	15	16	17	18	19	20			
To crib	216-B-47	216-B-47	216-B-46	216-B-48	216-B-49	216-B-49	216-B-46			
Date	9/21/55	9/28/55	10/18/55	11/2/55	11/25/55	12/12/55	12/21/55			
Gallons	569,250	403,560	591,250	555,500	591,250	552,750	572,000			
SAMPLE DATA										
pH	10.1	9.2	9.4	9.5	10.5	9.95	9.65			
Cs, μCi/mL	0.071	0.020	0.024	0.19	0.15	0.015	0.027			
Sr, μCi/mL	0.19	0.12	0.14	0.22	0.32	0.077	0.045			
Total β, μCi/mL	12.52	11.62	13.87	18.10	23.22	16.20	14.79			
Total α, cpm/gal	400,000	400,000	400,000	300,000	400,000	500,000	300,000			
PO_4, M	0.125	0.104	0.131	0.164	0.096	0.145	0.126			
U, lb/gal	0.50	2.40	0.10	0.10	68.0	23.0	72.7			
NO_3, lb/gal	1.40	1.45	1.60	1.60	1.67	1.26	1.14			
Solids, wt. %	29.0	25.6	29.9	32.2	33.3	22.5	20.8			
R.E., μCi/mL	0.29	0.21	0.30	0.78	1.17	1.48	0.98			
Ce, μCi/mL	1.86	1.76	1.36	0.95	0.74	2.69	0.47			
Zr-Nb, μCi/mL	1.18	1.34	1.21	0.96	2.02	2.85	3.01			
Ru, μCi/mL	5.60	4.07	1.30	2.39	1.47	6.26	5.49			
Sb, μCi/mL	0.79	0.65	0.40	0.59	0.49	0.91	0.71			

Curies are 1955 values; uncorrected for decay.

N/A: not analyzed
R.E.: rare earth elements

APPENDIX 7: FIGURES

INSERT FIGURES

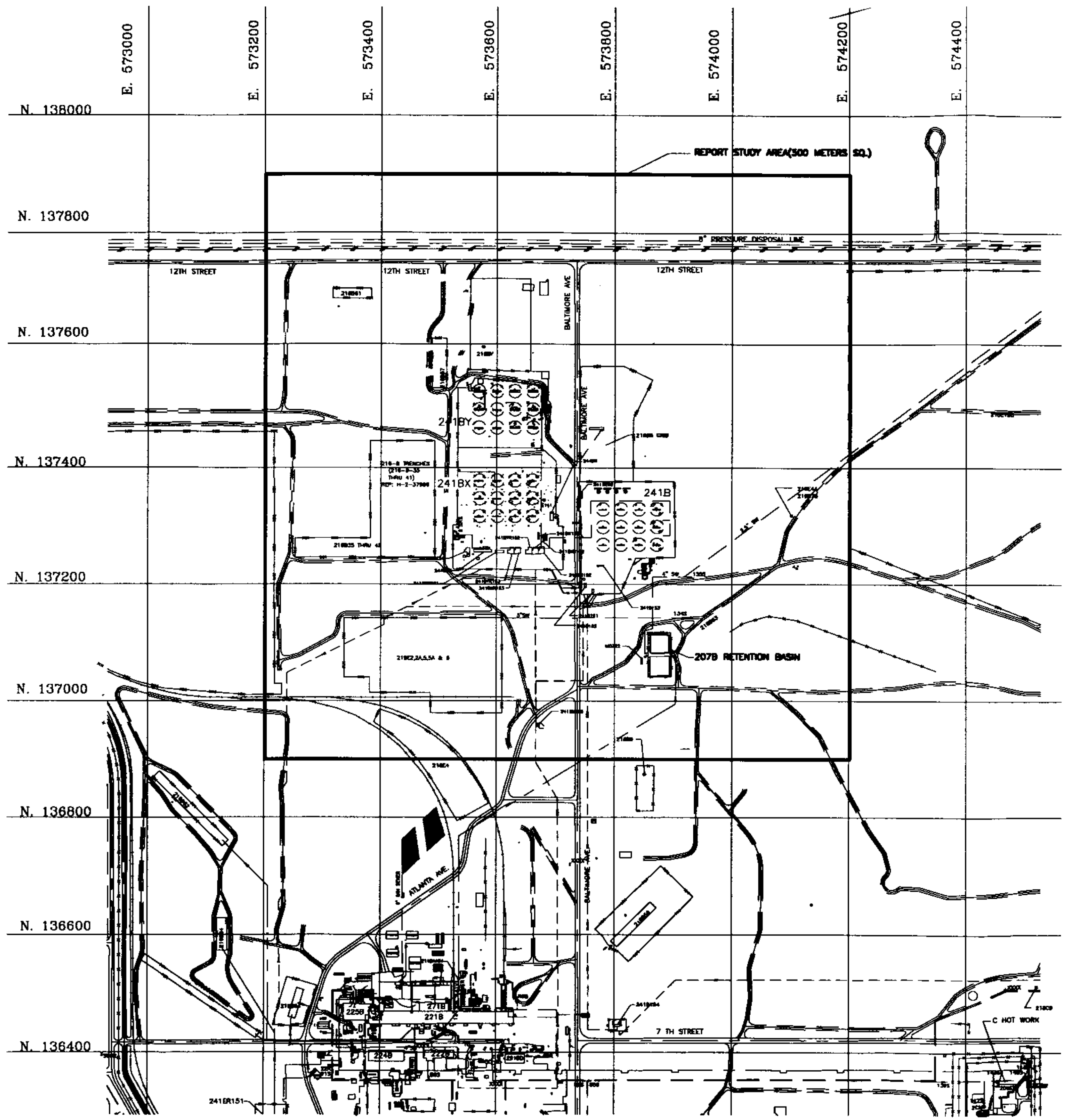
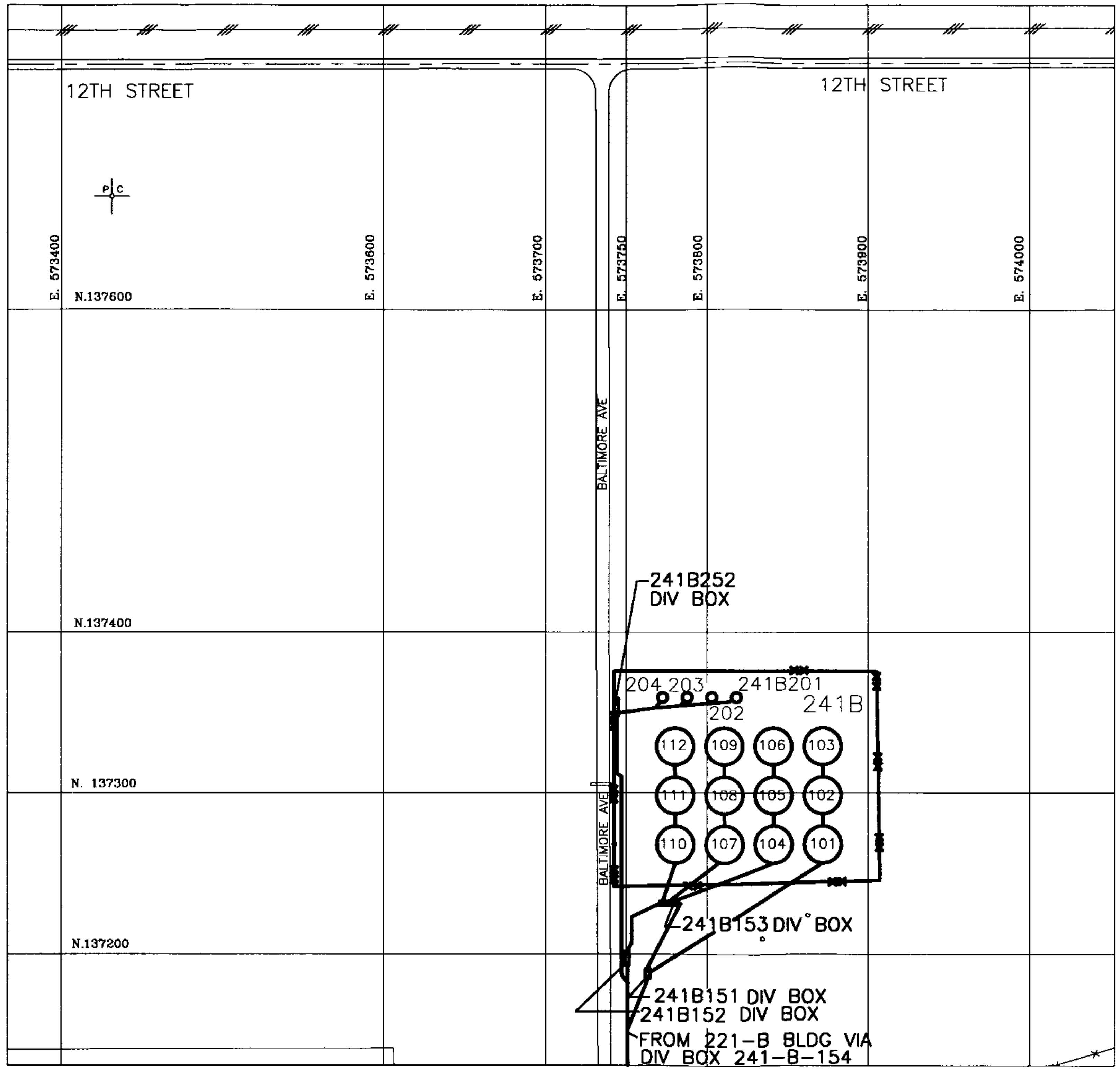


FIGURE 1 AREA OF INTEREST KEY PLAN

CRIB WELLS					
WELL NUMBER		Dia	Depth	DATE	FIG
SITE#	STATE#	in	ft	Installed	No
299-E33-073	A6881	8	150	01/01/48	3
299-E33-074	A6882	8	150	01/01/48	3
299-E33-075	A6883	8	150	01/01/48	3
299-E33-076	A6884	8	150	02/01/48	3
299-E33-079	A6887	8	12	10/01/48	3
299-E33-080	A6888	8	11	10/01/48	3
299-E33-081	A6889	8	14	11/01/48	3
299-E33-082	A6890	8	14	11/01/48	3
299-E33-089	A6897	8	150	12/01/47	3
299-E33-090	A6898	6	141	09/01/56	4
299-E33-091	A6899	6	146	08/01/56	4
299-E33-247	A7054	NA	NA	06/01/55	4
299-E33-271	A7072	NA	NA	06/01/55	4
299-E33-286	A7082	8	50	08/01/82	6
299-E33-287	A7083	8	50	08/01/82	6
299-E33-288	A7084	8	50	08/01/82	6
299-E33-289	A7085	8	50	08/01/82	6
299-E33-290	A7086	8	50	08/01/82	6
299-E33-296	A7092	8	227	03/01/92	6
299-E33-297	A7093	6	33	03/01/92	6
299-E33-298	A7094	6	30	04/01/92	6
299-E33-299	A7095	6	35	02/01/92	6
299-E33-300	A7096	6	38	05/01/92	6
299-E33-301	A7097	6	35	04/01/92	6
299-E33-302	A7098	6	223	01/01/92	6
299-E33-303	A7099	6	33	10/01/91	6
299-E33-304	A7100	8	235	10/01/91	6
299-E33-305	A7101	6	50	09/01/91	6
299-E33-306	A7102	6	50	09/01/91	6
299-E33-307	A7103	6	30	05/01/91	6
299-E33-308	A7104	8/6	29	12/01/91	6
299-E33-309	A7105	8/6	33	10/01/91	6
299-E33-310	A7106	8/6	32	12/01/91	6
299-E33-311	A7107	8/6	30	03/01/92	6
299-E33-312	A7108	8/6	32	12/01/91	6
299-E33-313	A7109	8/6	30	04/01/92	6
299-E33-314	A7110	8/6	31	05/01/92	6
299-E33-315	A7111	8/6	32	04/01/92	6
299-E33-316	A7112	8/6	32	03/01/92	6
299-E33-317	A7113	8/6	32	04/01/92	6
299-E33-318	A7114	8/6	30	01/01/92	6
299-E33-319	A7115	8/6	30	04/01/92	6
299-E33-320	A7116	8/6	35	05/01/92	6
299-E33-321	A7117	8/6	34	05/01/92	6
299-E33-322	A7118	8/6	31	04/01/92	6
299-E33-323	A7119	8/6	32	05/01/92	6
299-E34-008	A4883	6/4	240	12/01/91	6
299-E34-009	A4884	4	234.5	11/01/91	6
299-E34-010	A4875	4	249	10/01/91	6
299-E34-011	A4876	4	219	12/18/91	6

CRIB WELLS					
WELL NUMBER		Dia	Depth	DATE	FIG
SITE#	STATE#	In	ft	Installed	No
299-E27-016	A4814	NF	NA	4/17/90	6
299-E27-018	A6674	4	265	7/14/92	6
299-E28-005	A6787	6	327	03/31/48	3
299-E28-008	A6788	8	315	09/30/57	4
299-E28-010	A6789	8	325	08/31/61	5
299-E28-026	A4822	4	329	11/1/87	6
299-E28-027	A4823	4	301.4	09/1/87	6
299-E33-002	A4846	8	243	11/1/54	4
299-E33-003	A4854	4	236	11/1/54	4
299-E33-004	A4865	8	231	12/1/54	4
299-E33-005	A4870	8	238	6/1/55	4
299-E33-006	A6852	8	238	6/1/55	4
299-E33-007	A4871	8	233	4/1/55	4
299-E33-008	A4872	8	257	10/1/53	3
299-E33-010	A6853	6	290	04/01/55	4
299-E33-011	A6854	8	230	02/01/54	4
299-E33-012	A4839	4	415	09/01/53	3
299-E33-013	A4840	8	235	10/01/53	3
299-E33-014	A4841	8	230	12/01/53	3
299-E33-015	A4842	8	251	02/01/53	3
299-E33-016	A6855	8	258	01/01/53	3
299-E33-017	A4843	8	244	10/01/53	3
299-E33-018	A4844	8	278	02/01/50	3
299-E33-019	A4845	8	252	06/01/56	4
299-E33-020	A4847	8	254	07/01/56	4
299-E33-021	A4848	8	282	04/01/57	4
299-E33-022	A6856	6	232	08/01/65	5
299-E33-023	A6857	6	230	09/01/65	5
299-E33-024	A4849	8	256	05/01/67	5
299-E33-025	A6858	6	240	02/01/69	5
299-E33-026	A4850	6	240	03/01/69	5
299-E33-028	A6852	4	278	11/01/87	6
299-E33-029	A6853	4	290	09/01/87	6
299-E33-031	A4856	4	256	09/01/89	6
299-E33-032	A4857	4	270	09/01/89	6
299-E33-033	A4858	4	252	08/01/89	6
299-E33-035	A4860	4	249	06/01/55	4
299-E33-036	A4861	4	264	06/01/55	4
299-E33-037	A4862	4	240	06/01/55	4
299-E33-038	A4863	4	240	02/01/91	6
299-E33-039	A4864	4	229	02/01/91	6
299-E33-040	A4866	4	305	04/01/91	6
299-E33-041	A4867	4	263	?/91	6
299-E33-042	A4868	4	260	11/01/91	6
299-E33-043	A4869	4	276	11/01/91	6
299-E33-058	A6866	8	153	05/01/47	3
299-E33-059	A6867	8	153	05/01/47	3
299-E33-060	A6868	8	153	05/01/47	3
299-E33-066	A6874	8	150	11/01/47	3
299-E33-067	A6875	8	150	12/01/47	3
299-E33-068	A6876	8	150	12/01/47	3
299-E33-069	A6877	8	150	12/01/47	3
299-E33-070	A6878	8	150	12/01/47	3
299-E33-071	A6879	8	150	12/01/47	3
299-E33-072	A6880	8	150	12/01/47	3



241-B TANK FARM

FIGURE 2 FACILITIES CONSTRUCTED FOR THE MANHATTAN PROJECT, 1943 - 1945

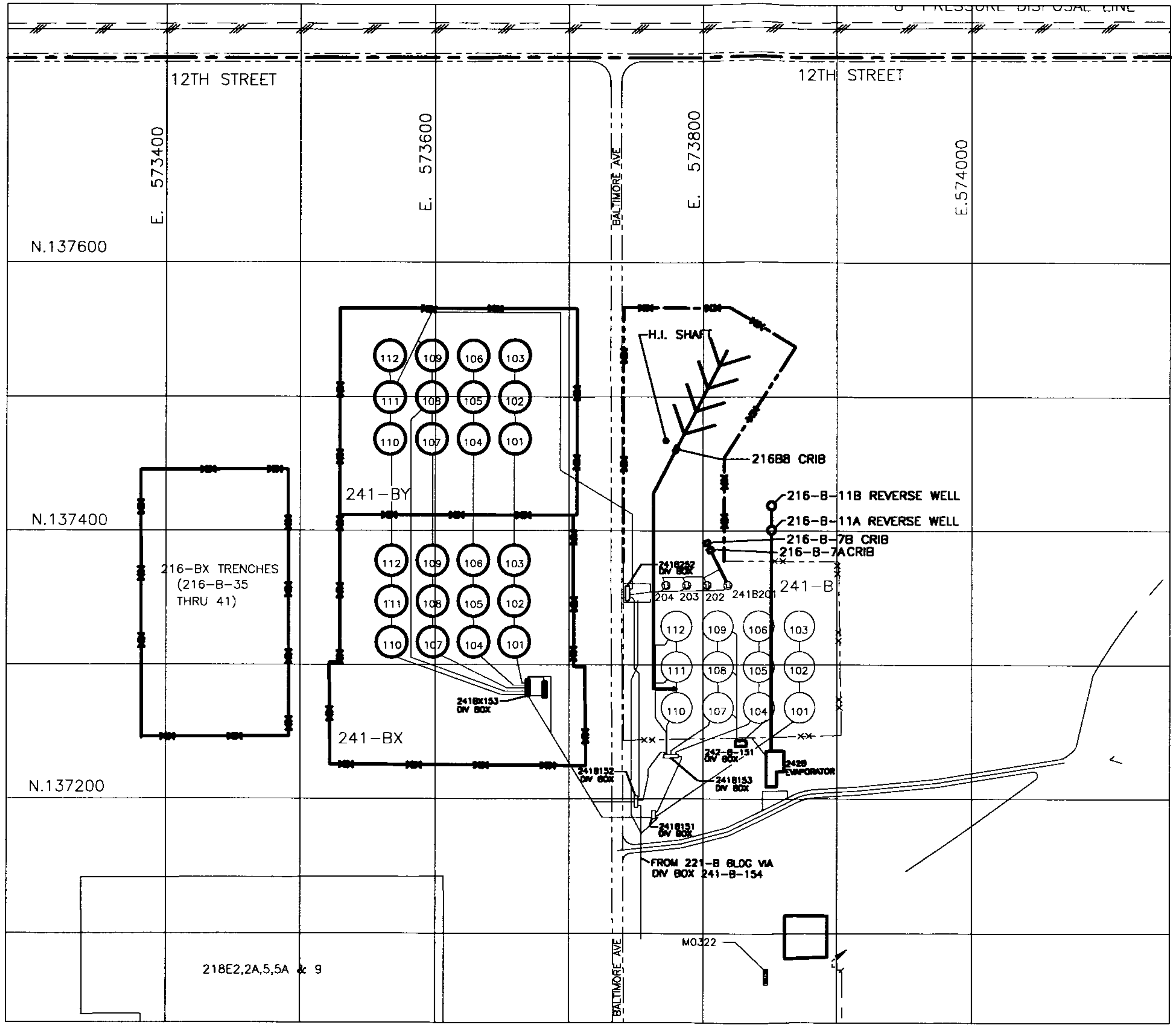


FIGURE 3, SH 1/2 FACILITIES CONSTRUCTED FOR POSTWAR BISMUTH PHOSPHATE OPERATIONS AND WASTE DISPOSAL, 1946 - 1953

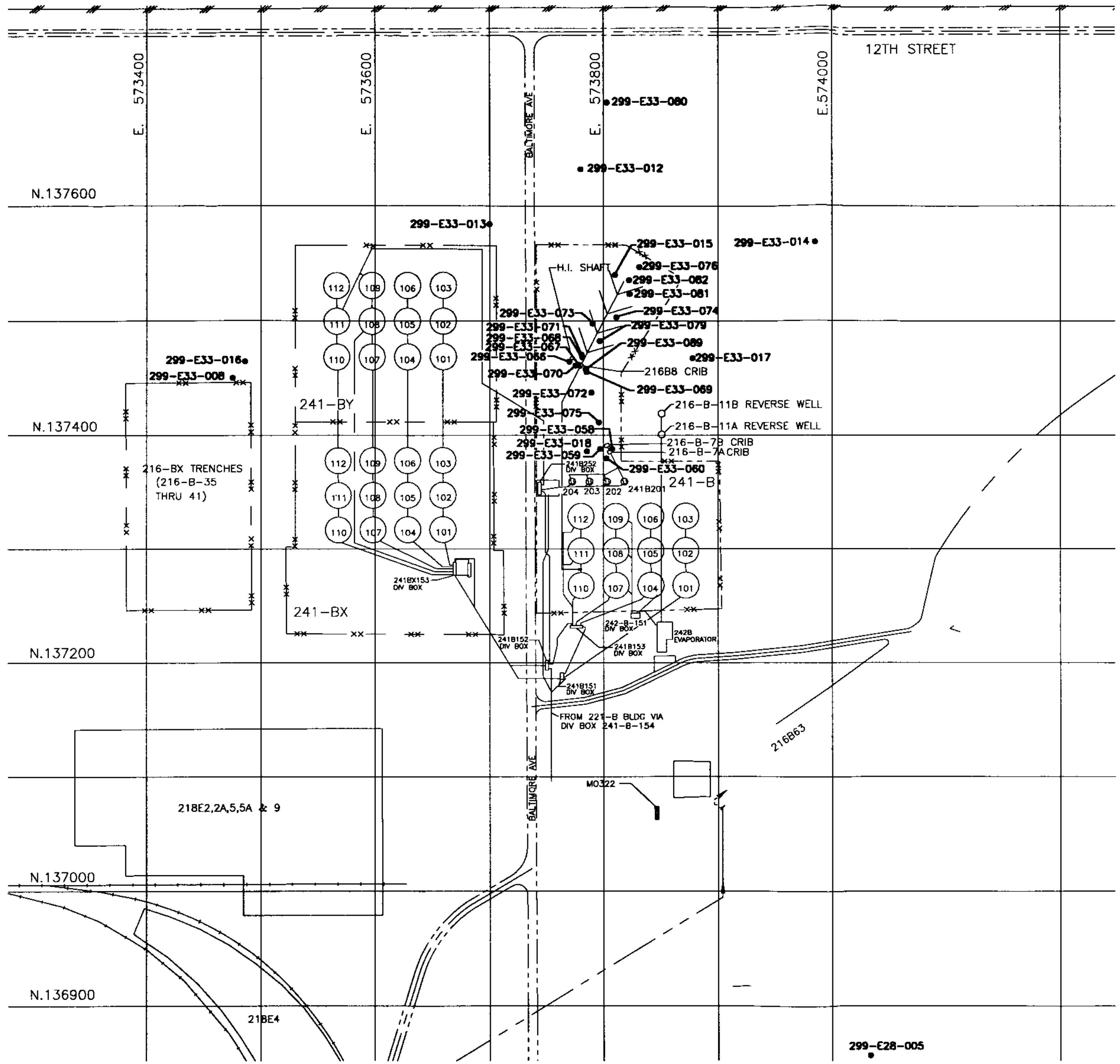


FIGURE 3, SH 2 FACILITIES CONSTRUCTED FOR POSTWAR BISMUTH PHOSPHATE OPERATIONS AND WASTE DISPOSAL, 1946 – 1953 (WELLS)

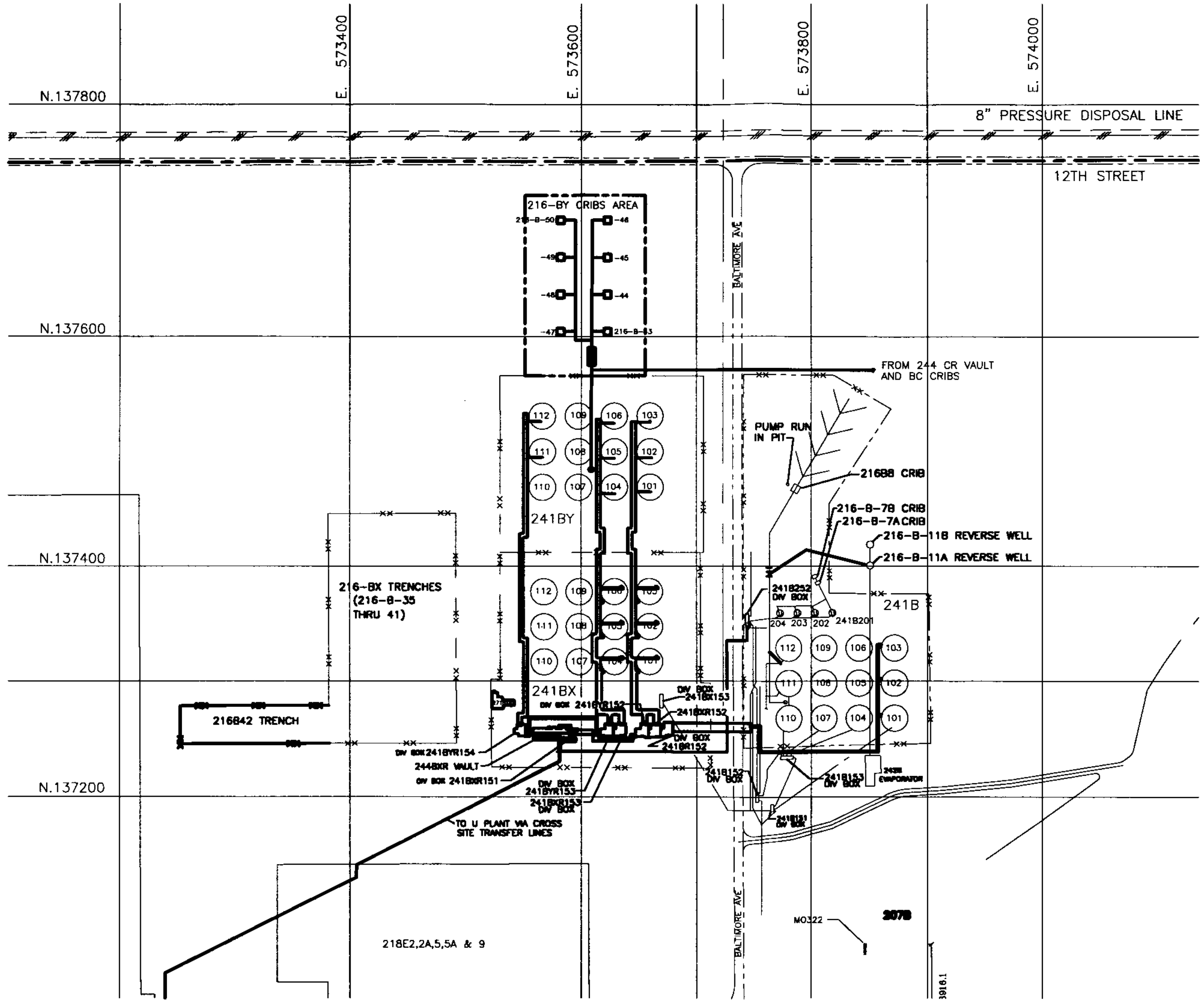


FIGURE 4, SH 1/2 FACILITIES CONSTRUCTED FOR URANIUM RECOVERY OPERATIONS, 1954-1958

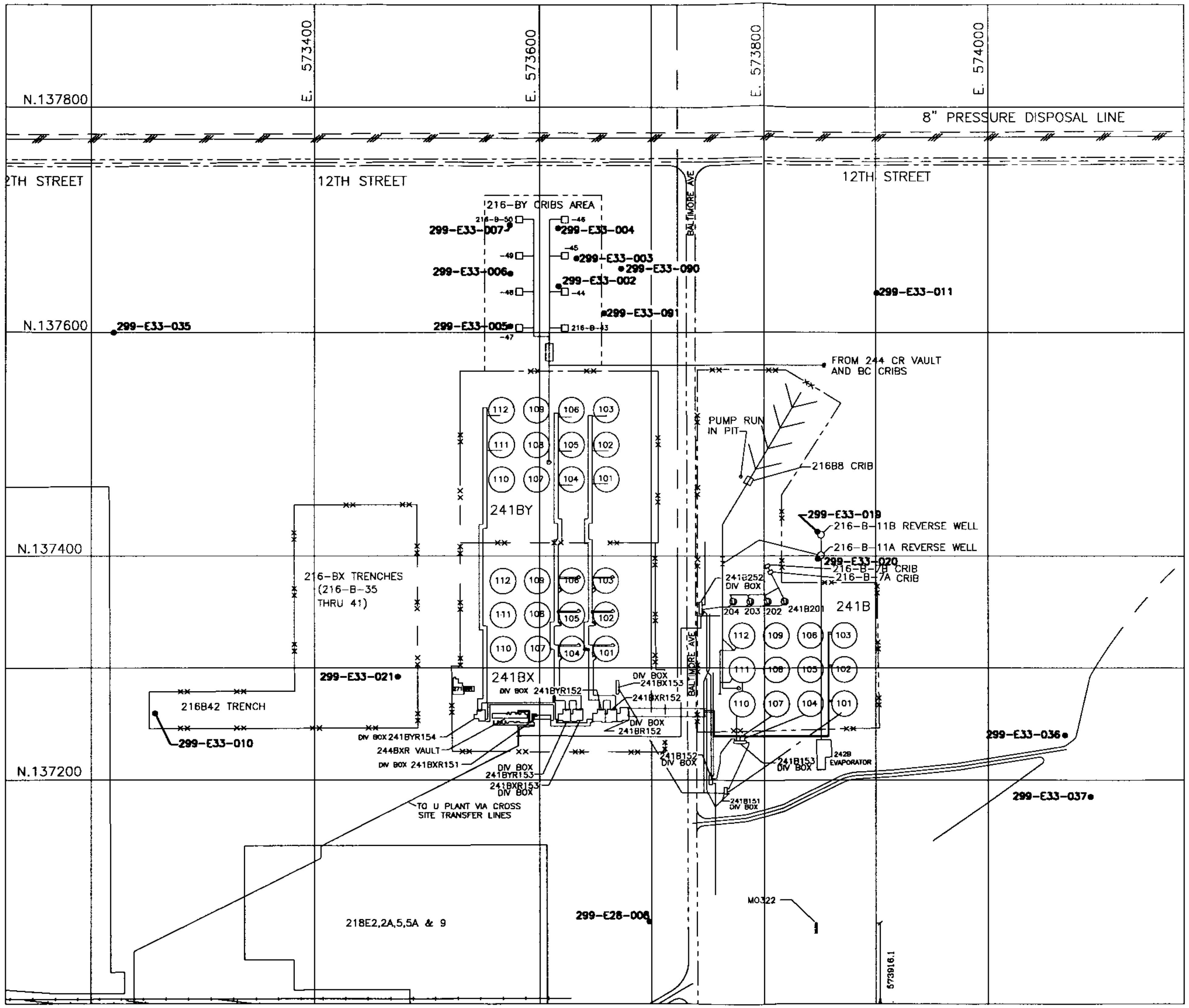


FIGURE 4, SH 2 FACILITIES CONSTRUCTED FOR URANIUM RECOVERY OPERATIONS, 1954-1958 (WELLS)

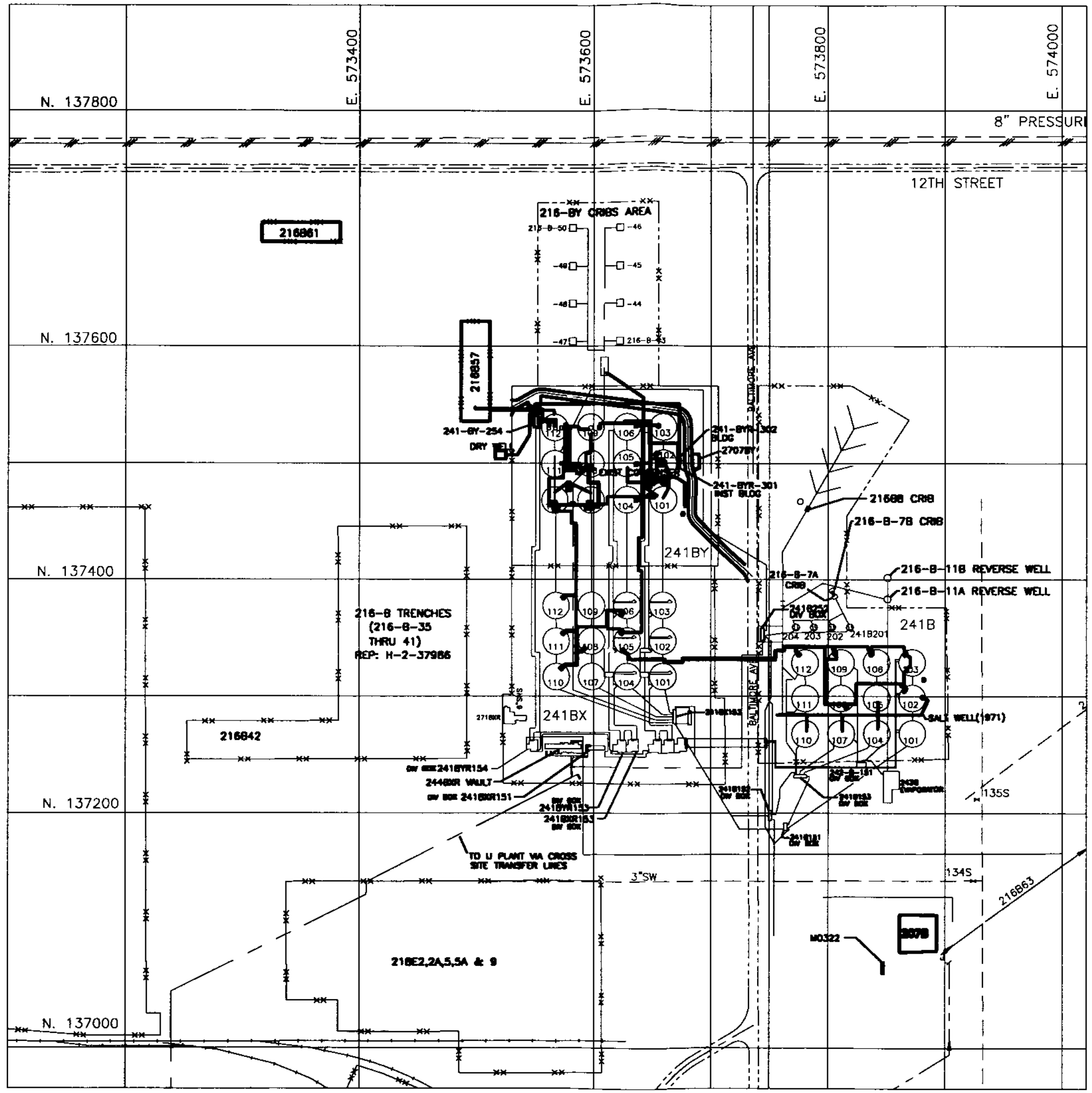


FIGURE 5, SH 1/2 FACILITIES CONSTRUCTED FOR IN-TANK SOLIDIFICATION, 1965–1975

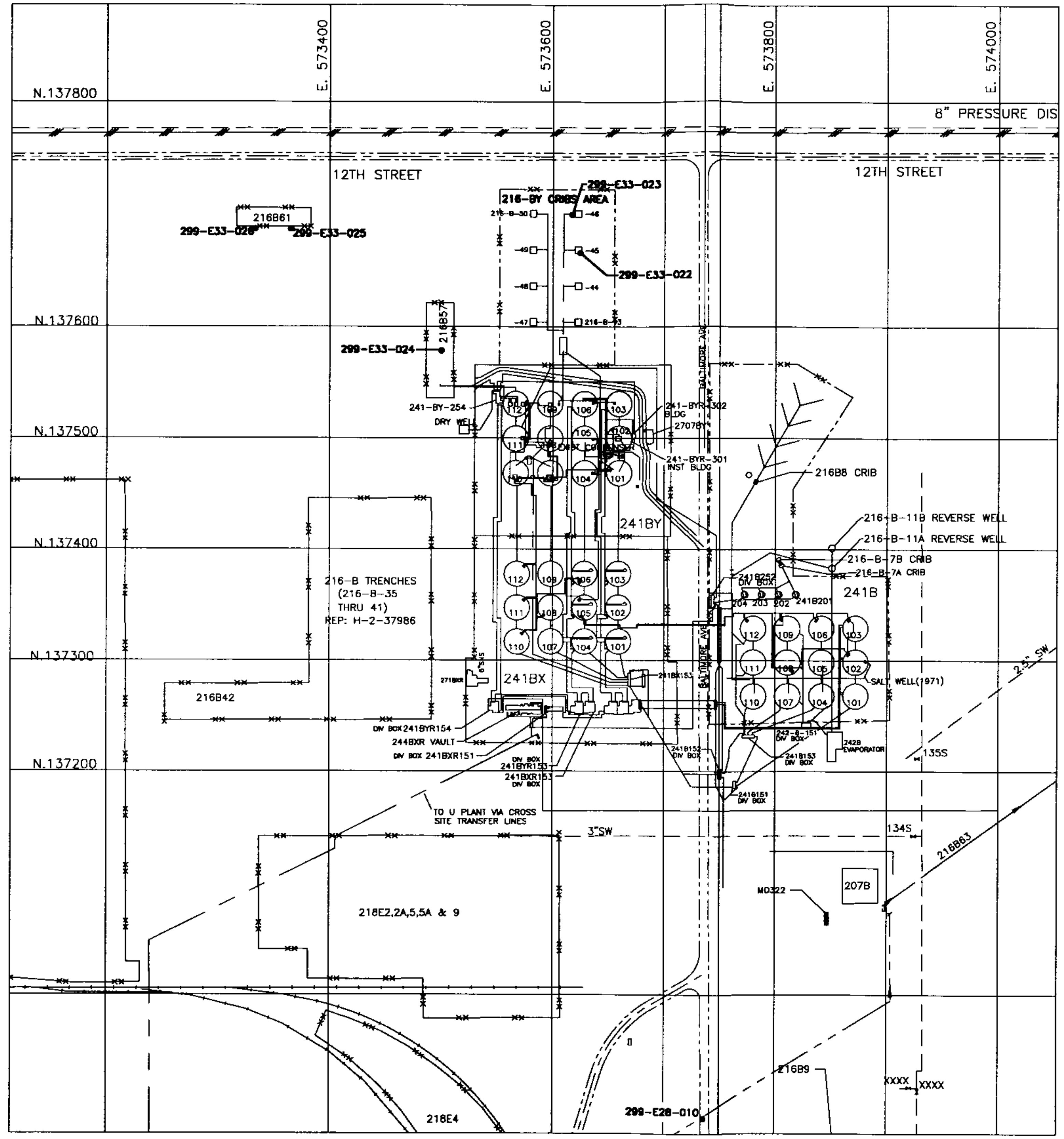


FIGURE 5, SH 2 FACILITIES CONSTRUCTED FOR IN-TANK SOLIDICATION, 1965-1974 (WELLS)

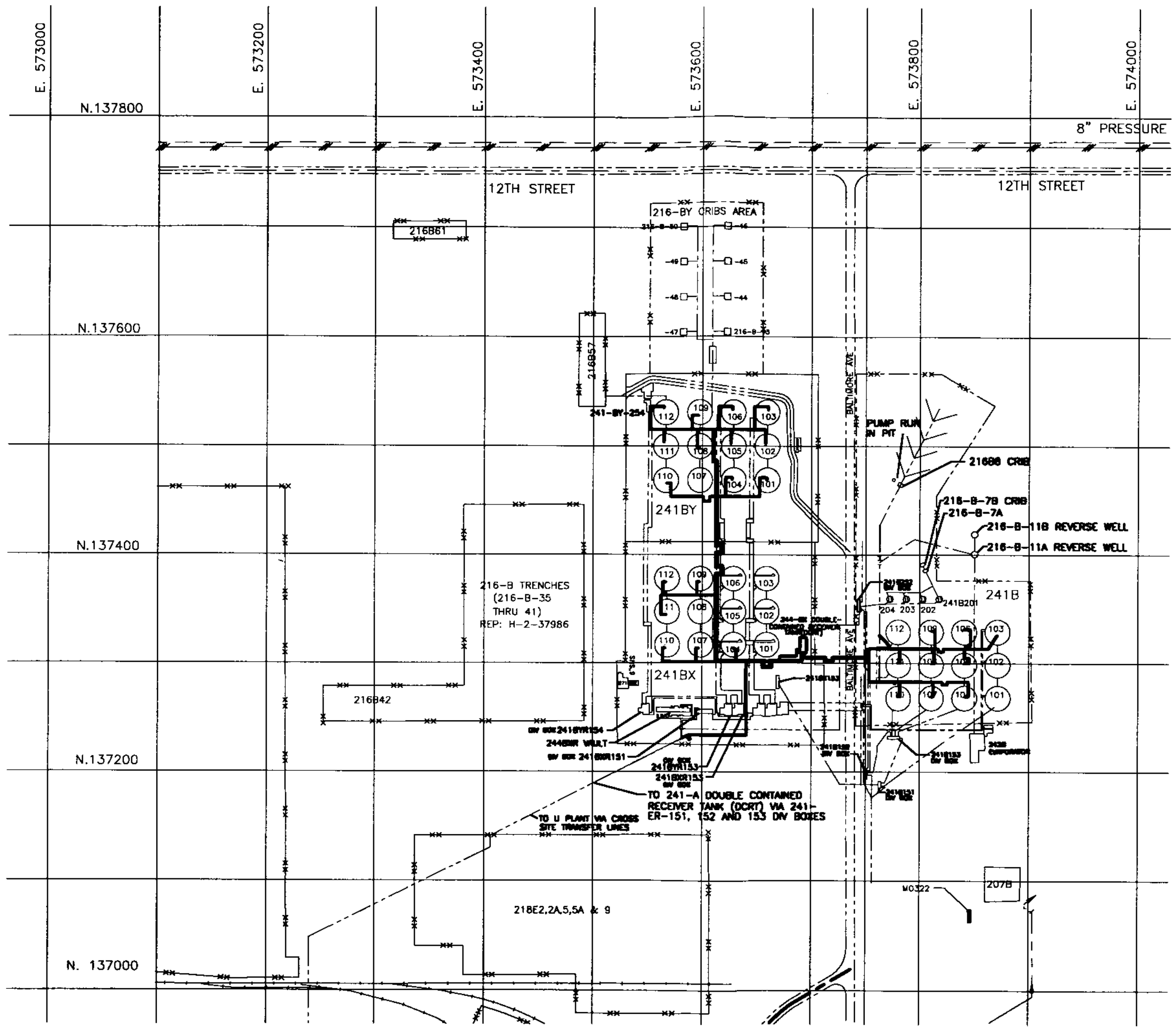


FIGURE 6, SH 1/2 FACILITIES CONSTRUCTED FOR TANK STABILIZATION (SALT WELL PUMPING) AND ISOLATION 1975-PRESENT

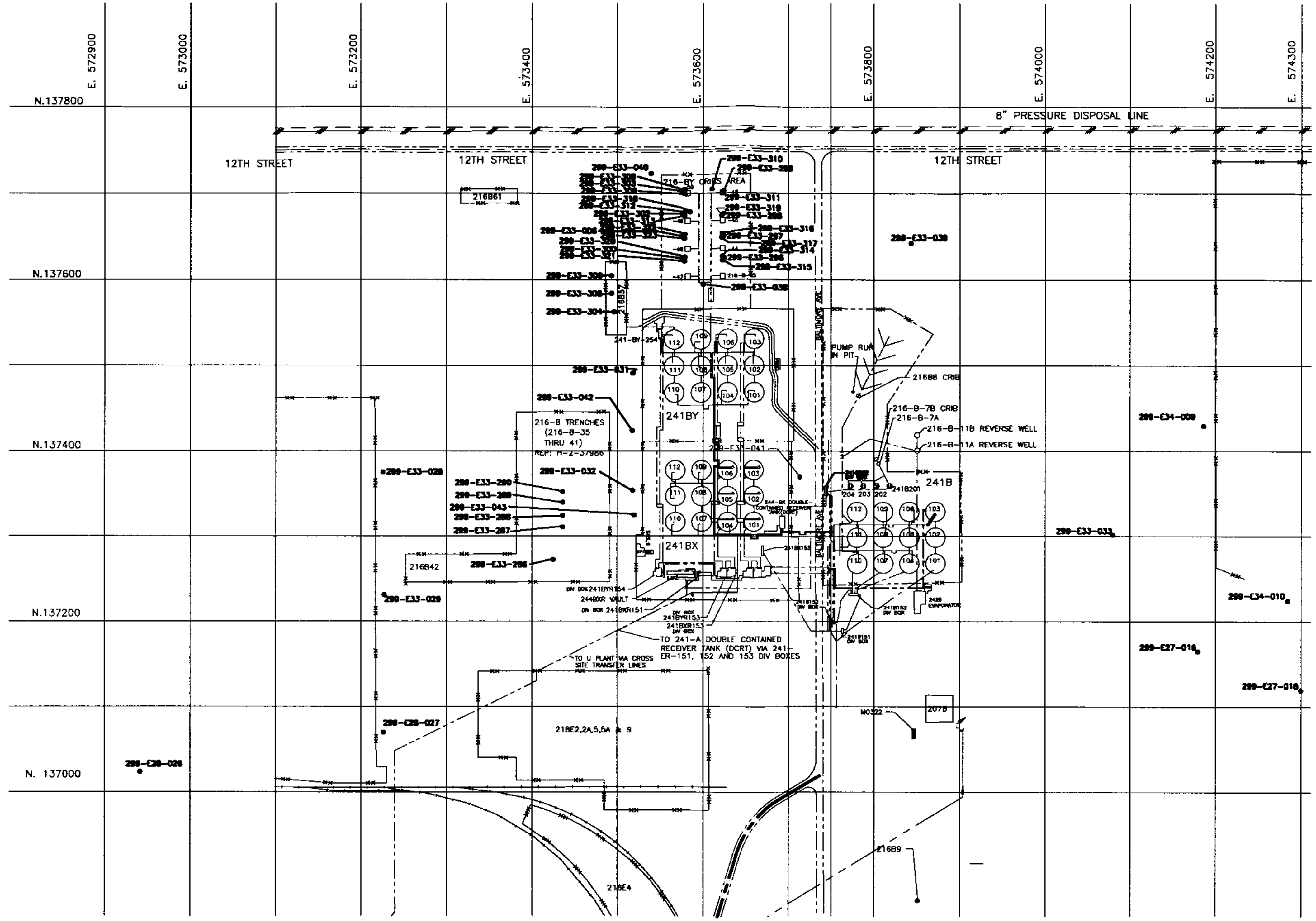


FIGURE 6, SH 2 FACILITIES CONSTRUCTED FOR TANK STABILIZATION (SALT WELL PUMPING) AND ISOLATION 1975–PRESENT(WELLS)

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